Supporting Information:

Room Temperature Lasing from Monolithically Integrated GaAs Microdisks on Si

Stephan Wirths, Benedikt F. Mayer, Heinz Schmid, Marilyne Sousa, Johannes Gooth, Heike Riel, and Kirsten E. Moselund

IBM Research – Zürich, Säumerstrasse 4, 8803 Rüschlikon, Switzerland

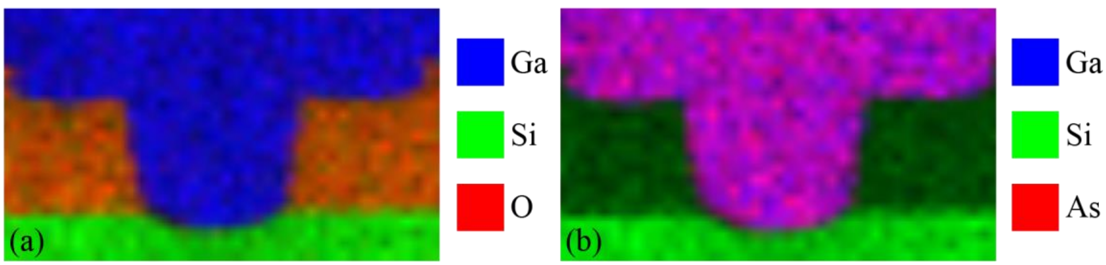

Figure S1. Energy Dispersive X-ray Spectroscopy (EDX) of a seed area from a fabricated GaAs microdisks showing (a) the Ga, Si and O as well as (b) the Ga, Si and As signal.

Figure S1 shows two Energy Dispersive X-Ray (EDX) maps of a TASE-grown AlGaAs-GaAs microdisk. Whereas in Figure S1a the oxygen signal is added to the Ga- and Si-signal, the As-signal is additionally shown in Figure S1b. These measurements have been performed with a JEOL ARM200F operated at 200kV and equipped with a liquid nitrogen free silicon drift detector. An image correction has been applied after each measured row. The absence of O at the III-V – Si interface indicates direct growth of the III-V gain material from the Si(001) seed area.

Figure S2 shows a microdisks that does not provide lasing action at all and exhibits highly defective or even polycrystalline segments.

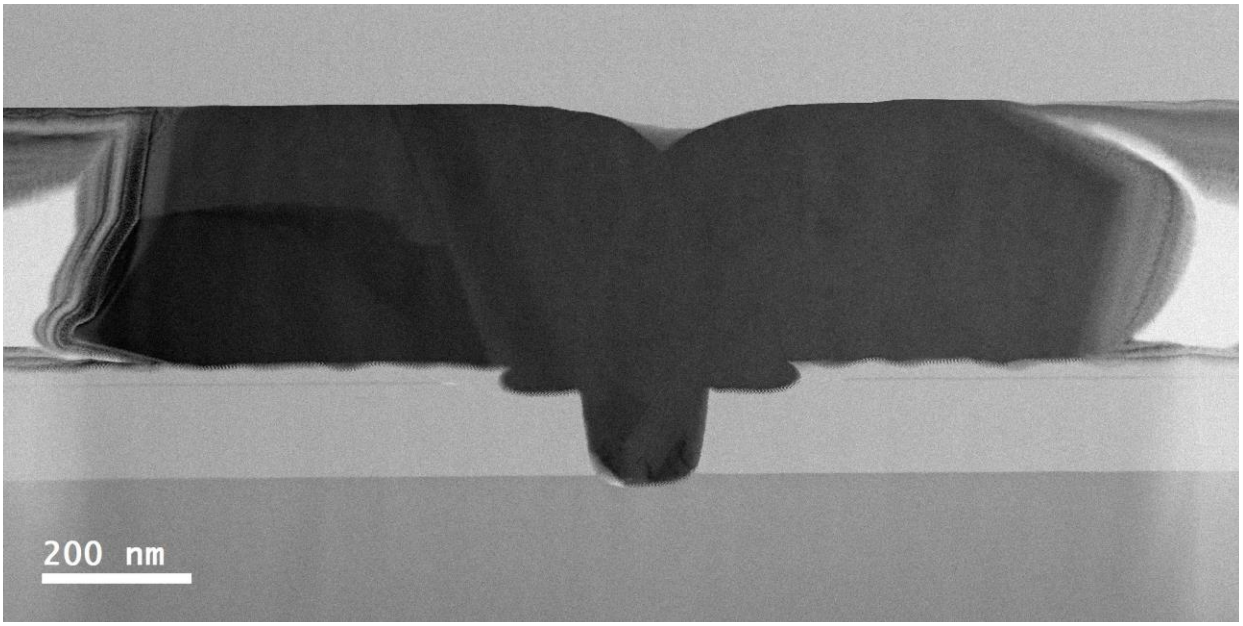

Figure S2. Cross section Scanning Transmission Electron Micrograph (STEM) of a microdisk device that does not show lasing action. This one consists of multiple grains and defects are growing from the seed region.

Figure S3 shows a line plot across diffraction spots obtained from the FFT of the device shown in the main text (c.f. Figure 2). One can observe that the measured distance between two diffraction spot is about the distance between the [6, 2,-2] diffraction spots of the simulated lattice (Fig. 2d).

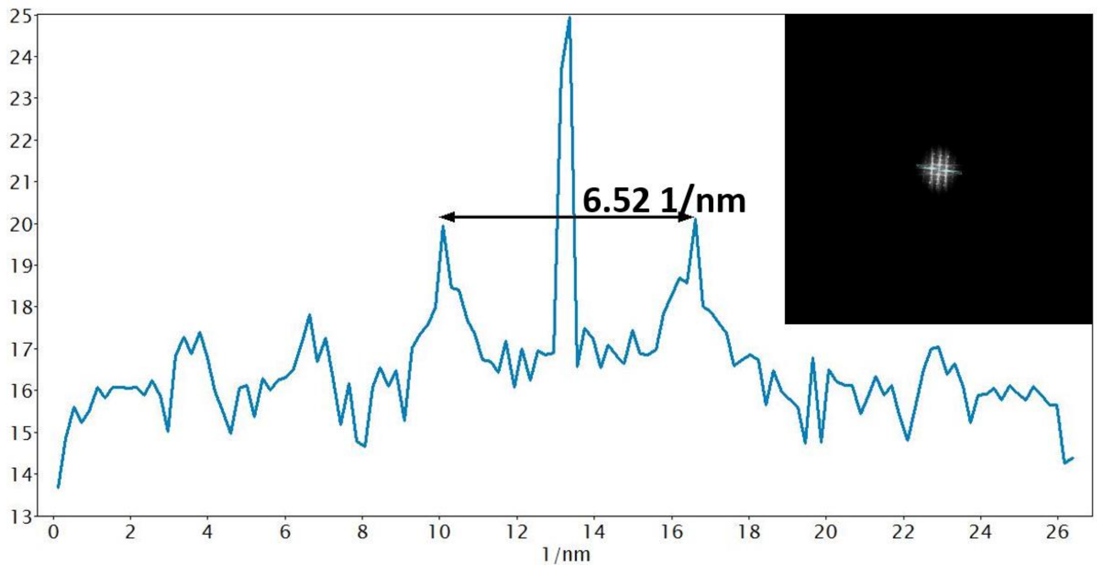

Figure S3. Line plot across diffraction spots obtained from the FFT of Fig. 2(d) (see inset).

FDTD simulations. In order to determine the lasing modes and the corresponding Q factors of the fabricated microdisks, we perform FDTD simulations using a random dipole method as schematically shown in Figure S3a. The method uses randomly oriented dipole sources that are placed on random positions into the GaAs microdisk and model the exciton emission of the GaAs gain material. We recorded the temporal and spatial evolution of the optical power and electric field intensity in the microdisk cavity, respectively. For a simulated time < 1000 fs, the dipoles exhibit a very complex emission patterns, however, for simulated time > 1600 fs, constructive and destructive interferences lead to the formation of distinct cavity modes until only those with the slowest decay time (highest Q-factor) remain. Figure S3b and S3c show FDTD simulations of a 1 µm and 3 µm microdisk cavity using the random dipole method, respectively. Although the mode profiles found for long simulation times are very different for the 1 µm and the 3 µm device, the cavity Q factors of Q = 1430 (1 µm) and Q = 1650 (3 µm) are similar. Therefore, we conclude that the ratio between the lasing thresholds of the two different devices (9:1) is mainly determined by the volume of the gain material, which reflects very well the findings presented in Figure 4 and Fig. 5 in the main manuscript.

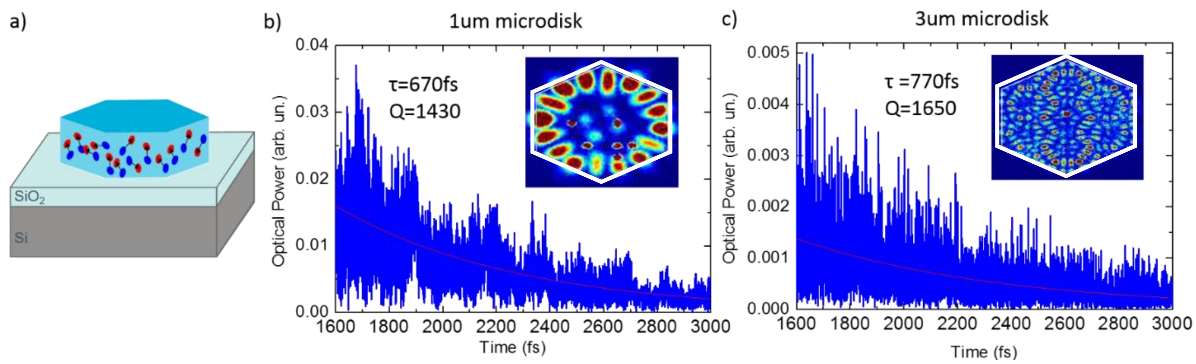

Figure S4: a) Schematic illustration of the simulation setup used for the random dipole calculations. b) Simulation of the optical power decay in a 1µm microdisk cavity using the random dipole method. The calculated photon lifetime in the microdisk cavity is τ_{ph} = 670 fs which corresponds to a cavity Q-factor of Q = 1430. The inset shows the electric field intensity profile of a remaining cavity mode. c) Simulation of the optical power decay in a 3µm microdisk cavity using the random dipole method. The calculated photon lifetime in the cavity is τ_{ph} = 770 fs which corresponds to a cavity Q-factor of Q = 1650. The inset shows the electric field intensity profile of a remaining cavity mode.